Inhomogeneous Shadowing Effects on J/ψ Production in dA Collisions

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The nuclear quark and antiquark distributions have been probed through deep inelastic scattering (DIS) of leptons and neutrinos from nuclei. These experiments showed that parton densities in free protons are modified when bound in the nucleus. This modification, referred to collectively as shadowing, depends on the parton momentum fraction x and the square of the momentum transfer, Q^2. Many models of shadowing predict that the modification should vary depending on position within the nucleus. Most DIS experiments have been insensitive to this position dependence. However, some spatial inhomogeneity has been observed in νN scattering.

Deuterium-nucleus collisions at heavy ion colliders offer a way to measure the structure functions of heavy nuclei at higher energies, hence lower x and higher Q^2 than currently possible with fixed target DIS experiments. In addition, dA collisions are more sensitive to the gluon distributions in nuclei than DIS. These dA collisions are preferred over pA collisions for technical reasons - the two beams have similar charge Z to mass A ratios, simplifying the magnetic optics. While shadowing measurements in pA and dA interactions have been discussed, the spatial dependence is unknown but is useful both as a probe of the shadowing mechanism and as an important input to AA collisions.

We show that dA collisions can be used to study the spatial dependence of nuclear gluon shadowing [1]. We consider two concrete examples: dAu interactions at $\sqrt{s_{NN}} = 200$ GeV at RHIC and 6.2 TeV dPb interactions at the LHC. We choose the J/ψ as a specific example since it has already been observed in pp and Au+Au interactions at RHIC and its production is dominated by gluons.

We assume that the nuclear parton densities, F_i^A, are the product of the nucleon density in the nucleus, $\rho_A(s)$, the nucleon parton density, $f_i^N(x,Q^2)$, and a shadowing ratio, $S^i_{\rm P,S}(A,x,Q^2,\vec{r},z)$, where $\vec{r}$ and z are the transverse and longitudinal location of the parton in position space. The first subscript, P, refers to the choice of shadowing parameterization, while the second, S, refers to the spatial dependence. Most available shadowing parameterizations ignore effects in deuterium. Thus,

$$\begin{aligned} F_i^d(x,Q^2,\vec{r},z) &= \rho_d(s) f_i^N(x,Q^2) \qquad (1) \\ F_j^A(x,Q^2,\vec{b}-\vec{r},z') &= \rho_A(s') S^j_{\rm P,S}(A,x,Q^2,\vec{b}-\vec{r},z') f_j^N(x,Q^2) \end{aligned}$$

where $s = \sqrt{r^2+z^2}$ and $s' = \sqrt{|\vec{b}-\vec{r}|^2+z'^2}$. In the absence of nuclear modifications, $S^i_{\rm P,S}(A,x,Q^2,\vec{r},z) \equiv 1$. The nucleon densities of the heavy nucleus are assumed to be Woods-Saxon distributions with $R_{\rm Au} = 6.38$ fm and $R_{\rm Pb} = 6.62$ fm. We use the Hulthen wave function to calculate the deuteron density distribution. The densities are normalized so that $\int d^2r dz \rho_A(s) = A$. We employ the MRST LO parton densities for the free nucleon and the Eskola *et al.* (EKS) and Frankfurt *et al.* (FGS) shadowing parameterizations. The FGS parameterization has stronger gluon shadowing. The results are shown in Fig. 1. The shapes are due to the modification of the gluon distribution in nuclei. Note that $S_{\rm P,\rho}$ has a stronger spatial dependence while the overall inhomogeneity is larger for $S_{\rm FGS,S}$.

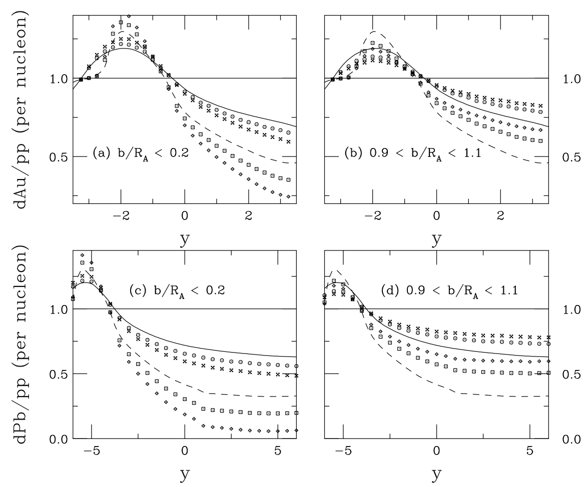

FIG. 1: The J/ψ shadowing ratio for (a and b) 200 GeV dAu collisions and (c and d) 6.2 TeV dPb collisions as a function of rapidity. The results are shown for EKS98 (solid line, circles and x's for $S^i_{\rm EKS98,WS}$ and $S^i_{\rm EKS98,\rho}$ respectively) and FGS (dashed line, squares and diamonds for $S^i_{\rm FGS,WS}$ and $S^i_{\rm FGS,\rho}$ respectively). The impact parameter bins are (a) and (c) $b/R_A < 0.2$, (b) and (d) $0.9 < b/R_A < 1.1$.

[1] S. R. Klein and R. Vogt, Phys. Rev. Lett. **91**, 142301 (2003).